

ECONOMICS OF THE SHEEP BREEDING OPERATIONS
OF THE DEPARTMENT OF LANDS AND SURVEY

A.T.G. McArthur

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PREFACE

Performance recording is an important tool that can be used by sheep breeders in sheep selection. Raising the average performance of the flock via such a procedure is a mechanism whereby output can be increased from farms without increasing sheep numbers. Alternatively, with higher per head performance, the same output can be achieved at a lower cost.

This report, written by Dr A.T.G. McArthur, reader in the Department of Agricultural Economics and Marketing at the College, gives an economic evaluation of a performance recording scheme used by the Department of Lands and Survey. The evaluation is effected in terms of an equivalent annual return and is subjected to an uncertainty analysis.

Economic evaluations of such technologies and procedures are important if decision makers are to be guided as to the efficiency and distributional effects of different actions.

P D Chudleigh
Director

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SUMMARY

This report presents an economic evaluation of the Department of Lands and Survey sheep breeding operations which depend upon recording and an open nucleus breeding system. The decision problem is defined as the continuation of this system of breeding compared with the reversion to buying rams from the pedigree breeding industry. The evaluation assumes that the breeding system will continue after the land is sold to settlers.

The additional benefit per ewe is expected to rise by \$0.18 per year to \$7.20 after ten generations of selection. This has an equivalent annual return per ewe of \$3.75 amounting to \$800,000 annually over the total ewes involved of 209,000. An uncertainty evaluation established that it is very highly probable that the project will break-even or better. It is on the grounds of the increase in economic efficiency that this evaluation points to the continuation of the project.

CHAPTER 1

INTRODUCTION

The Rotorua Land Development District of the Lands and Survey Department has the function of developing blocks of unimproved land under station management and then subsequently subdividing these blocks for sale to settlers. In the process of land development the Department operates as a large scale sheep and cattle owner. Currently the ewe flock stands at 209,000 Romney ewes.

Until 1967, the Department bought rams from pedigree breeders. Then there was a change in breeding policy. The Department established a nucleus flock at Waihora Station by selecting superior ewes from its flocks in the Rotorua District. The Waihora flock of 9,000 ewes is being improved by using the best rams and the best ewes from this nucleus. Ewes with outstanding performance in the other flocks (referred to as the base) are also "promoted" to the nucleus. This organisation of selection is called an Open Group Nucleus Breeding System. (For details of the system see Hight, Gibson, Wilson and Guy, 1975 .)

There were three reasons why the Department of Lands and Survey abandoned the traditional method of buying rams from pedigree breeders and moved over to a system of sheep improvement within their own flocks.

Firstly, the objectives, methods of measurement and methods of selection used by the pedigree breeding industry at that time did not result in expectations for genetic gain in the commercial traits of interest to the Department of Lands and Survey. If at some time in the past, the pedigree population had some genetic superiority above Department's stock with respect to their commercial traits, this difference would have been reduced to a small fraction of the initial difference through the policy of buying pedigree rams for use in the Department's flocks. For example, after five generations of grading up to a pedigree population an initial difference would be reduced to $(\frac{1}{2})^5$ or 0.03 of the initial difference. Only if the pedigree breeding industry had been pursuing the objectives required by the Department,

could flock improvement be expected from buying pedigree rams. Empirical observations of the performance of Lands and Survey sheep showed a static lambing percentage. This is consistent with the expectation that no improvement in genetic ability was occurring through buying pedigree rams (Hight et al, 1975).

Secondly, a large scale open nucleus breeding system combined with selection based on records had expectations for improving commercially important traits. Improved sheep confer benefits to the nation whether they are owned by the Department of Lands and Survey or are taken over at settlement by farmers.

Thirdly, the breeding systems for sheep based on recording had been recommended by leading animal scientists (Rae, 1970). Experience both in New Zealand and overseas with poultry, pigs, dairy cattle, and sheep had shown that the predicted gains from objective selection were forthcoming in practice. The Department of Lands and Survey recognised the external economic benefits of demonstrating to the sheep industry the application of objective selection in practice. The Department has a long history of successful demonstration in the field of land development. Its large scale land development activities have provided useful information and confidence to private land developers. Demonstration of modern sheep breeding can be expected to give confidence to private commercial farmers and some will follow the Department's lead as they have with land development.

The change in breeding policy by the Department in 1967 resulted in criticism from pedigree Romney breeders. As an important market for rams, the decision by the Department to breed its own rams as a 'substitute' for pedigree rams must have shifted the demand curve for pedigree rams to the left. Romney Breeders became more concerned in 1980 when the Department started selling rams from its nucleus flock to private farms resulting in a further shift to the left of their demand curve. This has brought further criticism of a public agency entering a private market.

The long term future of the Open Nucleus Breeding System established in the Rotorua Land District is also under discussion. In the next decade the stations could be broken up into farms and settled.

The question arises to what the government should do with the Waihora nucleus that it has established.

These policy questions will be discussed at the end of this report. But before they can be discussed, it is necessary to establish whether or not the social benefits of the sheep breeding operation of the Department outweigh the social costs. This is the main purpose of the research project presented in this report.

The report first estimates the technological gains in the Romney sheep in the Lands and Survey Land District and then translates these into estimated social benefits. Together with estimates of cost, the net benefits are estimated, upon which recommendations are based.

CHAPTER 2

TECHNOLOGICAL GAINS FROM SHEEP BREEDING OPERATIONS

2.1 The Sheeplan Approach

The selection objectives used by the Department of Lands and Survey are very similar to those defined in the national recording scheme for sheep, known as Sheeplan. Sheeplan is designed to improve the genetic ability of ewes with respect to four traits (Clarke and Rae, 1976).

1. The average number of lambs born per lambing (NLB).
2. The weaning weight of lambs (WWT).
3. The spring liveweight (SLW).
4. The hogget fleece weight (HFW).

The Department selects for numbers of lambs weaned rather than number of lambs born as a minor variant of Sheeplan.

An obvious connection exists between NLB, WWT, and HFW traits and economic gains. Spring liveweight (SLW) is included as a selection objective because selection for it will improve the other traits. The transformation of gains in these traits into economic terms will be left until later.

The main thrust of selection used by the Department is to select two-tooth rams and ewes on the bases of information on the fertility of their mothers, their own weaning weights, their own spring live-weights, and their own hogget fleece weights.

Using procedures similar to those used in Sheeplan, the actual records are expressed as deviations from contemporary sheep - sheep born in the same year on the same farm. These deviations are also corrected for a number of environmental factors which are known to influence performance. The appropriate correction factors are estimated from the data available from all Waihora recorded sheep. The corrected records are used to estimate the genetic value of each two tooth in line for selection for the four traits.

The estimated genetic values for the four traits are weighted by their so-called relative economic values. These relative economic weights are shown in Table 1.

TABLE 1
Relative Economic Weights

Trait	Relative Economic Weight
NLB	554 cents per lamb born
WWT	24 cents per kilo of live weight
SLW	0 cents per kilo of live weight
HFW	92 cents per kilo of greasy wool

These relative economic weights were derived from average prices in the 1970-1975 period.

The estimated genetic values of each of these traits are weighted by the relative economic weights (each genetic value is multiplied by the appropriate weight and the products added up) to give an estimate of each two-tooth's aggregate genotype. This is the estimated genetic superiority of the two-tooth above its contemporaries measured in cents. This estimate is called the selection index. The theory of the construction of selection indexes has been summarised by Cunningham (1969).

Rather than this two-step procedure of estimating the genetic value for each trait and then weighting these by the relative economic weights, the aggregate genotype or selection index can be calculated in one step. This is done by weighting the records for NLB on the dam and the individual's WWT, SLW, and HFW by a set of so-called 'b' values. The set of b values varies somewhat with the number of records the dam possesses in order to assess her NLB (average number of lambs born). But for the modal case of a dam with three lambings the b values are shown in Table 2.

These b-values incorporate both technical and economic information (see Table 1) to provide the best estimate of the two-tooth's aggregate genotype in cents.

TABLE 2
b-Values for a 3-Lambing Dam

Observed Record	b-values
NLB on dam	63.8
WWT on individual	3.2
SLW on individual	5.6
HFW on individual	0.017

Selection of parents on the basis of the index results in genetic gain in numbers of lambs born, weaning weight, spring live-weight, and hogget fleece weight. The standard deviation of indexed animals is 42 cents. Suppose that two-tooth rams and ewes selected as parents of the next generation averaged 42 cents above their contemporaries or 1 standard deviation of the index. The predicted genetic gain in NLB, WWT, SLW, and HFW in their offspring is shown in Table 3.

TABLE 3
Genetic Gain in Offspring
For Parents 1 Standard Deviation Above Contemporaries

Trait	Genetic Gain
NLB	0.05 lambs born
WWT	0.5 kilos liveweight
SLW	1.2 kilos liveweight
HFW	0.03 kilos greasy wool

The genetic gains given in Table 3 strictly refer to the gains where all selected two-tooths have mothers who have had three lambings. This is the modal case at Waihora. The gains are not very different where the index is based on more or less records.

Table 3 shows that in the case where parents are 1 standard deviation above contemporaries on the index, the response will be an extra 0.05 lambs per lambing in the next generation. Continued

selection would be expected to show a diminishing response because genetic variability is reduced as a result of selection. However, small animal experiments indicate that the degree of curvature of the response curve to selection is small (Falconer, 1964). In this study a linear response for 10 generations with no response in spite of selection pressure thereafter is assumed. In other words the gain in numbers of lambs born after ten generations is 10 times the gain in one generation, but thereafter no further gains are assumed. This is illustrated in Diagram 1.

2.2 Open Nucleus Gains

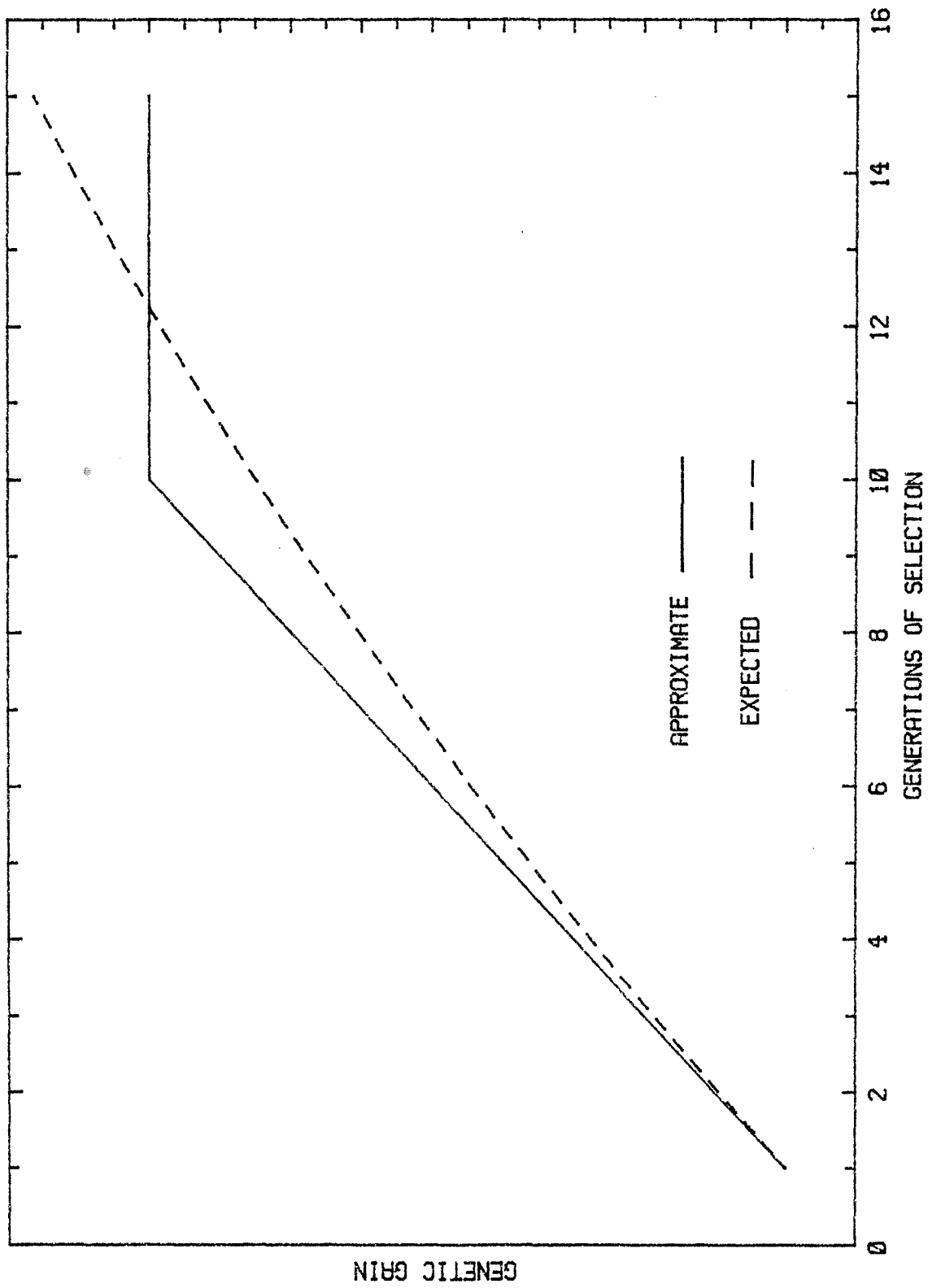
The open nucleus system in the Rotorua Land Development District has 4.9 per cent of ewes in the Waihora nucleus and the remaining 95.1 per cent in its base flocks. (All the estimates for the Waihora nucleus in this section have been supplied by Craig (1981) pers. comm.). It operates as follows.

The nucleus flock at Waihora is recorded under a variant of Sheeplan in co-operation with the Ministry of Agriculture and Fisheries. All ram and ewe two-tooths have indices calculated and the best ram two-tooths born in the nucleus are retained for use in that flock. All rams must meet basic culling levels for traits not in the index. Of those that meet these criteria, the best 7.3 per cent are selected on the basis of their indices for use in the nucleus. The next best 63.6 per cent are selected for use in the base flocks.

In the same manner, the best two-tooth ewes born in the nucleus are retained representing the top 72.7 per cent on index. A small and insignificant number of ewes including two-tooths are relegated to the base flocks from the nucleus which are ignored in the analysis because their numbers are not sufficient to influence the results.

The base flocks are not recorded. However, the practice is for two-tooth ewes to be mated and if they produce twins or better, they are promoted as four tooths to join the nucleus flock. Ten per cent of the two-tooths rear twins or better. If the base ewes were indexed in the same way as the nucleus flock, then selecting the best 17 per cent

DIAGRAM 1
SELECTION RESPONSE



on an index would result in selected animals with a genotype of the same economic value as selecting the best 10 per cent merely on their reproductive performance as two-tooths.¹

Beyond this promotion of fertile ewes from the base to the nucleus, there is effectively no selection within the base flock. The effect of promoting fertile ewes results in 20.7 per cent of the ewes in the nucleus flock having been born in the base. The promotion process gives rise to the term 'open' nucleus as opposed to a closed nucleus system where the nucleus is closed from genetic introductions.

The proportion of the population selected for breeding because they have the best selection indices is referred to as the selection intensity. Assuming that the index as measured in two-tooths is normally distributed, the selection intensities for rams and ewes can be transformed into selection differentials. Selection differentials measure the average deviation of the index of a selected group of parents from the mean of the population from which they were selected in standard deviation units. Table 4 shows the selection intensities and differentials for rams born and used in the nucleus, rams born in the nucleus but used in the base, ewes born and used in the nucleus, and ewes born in the base and promoted to the nucleus.

¹ Selecting the best 10 per cent of two-tooths on the basis of reproductive performance implies a selection differential of 1.75 standard deviations in NLB. NLB has a phenotypic standard deviation of 0.65 with a heritability of 0.1 (Clarke and Rae, 1965). The economic value of an extra lamb born is 554 cents (Table 1). The estimated genetic economic value of the best 10 per cent of twinning two-tooths is $1.75 \times 0.65 \times 0.1 \times 554 = 63$ cents. Selecting the best 17 per cent of ewe two-tooths on the basis of their index implies a selection differential of 1.48 standard deviations. From Table 1 and Table 3, the estimated genetic economic value of this best 17 per cent is $1.48 (.05(554) + .5(24) + .03(92)) = 63$ cents.

TABLE 4
Selection Intensities and Differentials

Sex	Born In	Used In	Selection Intensity	Selection Differential	Symbol for Selection Differential
Ram	Nucleus	Nucleus	Best 0.073	1.8993	D_{RN}
Ram	Nucleus	Base	Next Best 0.636	0.3210	D_{RB}
Ewe	Nucleus	Nucleus	Best 0.727	0.4572	D_{EN}
Ewe	Base	Nucleus	Best 0.17	1.4884	d_{EN}

Procedures have been developed by James (1974) for estimating the genetic gains in open nucleus breeding systems. These have been modified to analyse the specific circumstances of the breeding operations of the Department.

The weighted selection differential in the nucleus (C_N) is given by:

$$C_N = \frac{1}{2}(D_{RN} + (1 - x) D_{EN} + x d_{EN}) \quad (1)$$

where x is the fraction of nucleus ewes which are promoted from the base

$$\begin{aligned} &= \frac{1}{2}(1.8993 + (1 - .207)0.4572 = (.207)1.4884) \\ &= 1.285. \end{aligned}$$

The weighted selection differential in the base (C_B) is given by:

$$C_B = \frac{1}{2} D_{RB} = \frac{1}{2}(0.321) = 0.161 \quad (2)$$

The genetic gains in the nucleus (G_N) measured in standard deviation units is:

$$G_N = C_N - \frac{1}{2}xA \quad (3)$$

and the genetic gains in the base (G_B) is

$$G_B = C_B + \frac{1}{2}A \quad (4)$$

where A is the genetic difference between the nucleus and base in the previous generation.

After several generations of selection the genetic difference between nucleus and base becomes independent of any initial genetic

difference established when the nucleus system was set up and stabilises at A^* .

$$A^* = \frac{2(C_N - C_B)}{(1 + x)} \quad (5)$$

$$= 2(1.285 - 0.161) / (1 + 0.207) = 1.862$$

The Waihora nucleus is not run under identical environmental conditions to the flocks in the base so that A cannot be estimated directly. It has been assumed that a stable genetic difference between the nucleus and the base has now been established of 1.862 standard deviation units on the index. The genetic gain per generation in both nucleus and base are then equal. From equations 3 and 4:

$$G_N = C_N - \frac{1}{2}xA^* = 1.285 - \frac{1}{2}(0.207)1.862 = 1.092$$

$$G_B = C_B + \frac{1}{2}A^* = 0.161 + \frac{1}{2}(1.862) = 1.092$$

Hence the expected advance in the index in both the nucleus and the base is 1.092 index standard deviations per generation with a constant superiority of the nucleus of 1.862 index standard deviations.

The gain of 1.092 index standard deviations of aggregate genotype can be transformed into per generation gains on the four traits - number of lambs born, weaning weight, spring liveweight and hogget fleece weight. This is simply done by multiplying genetic gain coefficients in Table 3 by the gain of 1.092 in index standard deviations as shown in Table 5. By dividing the genetic gain per generation by the average generation interval of 3.4 years, the gain average for each trait can be calculated.

TABLE 5

Gain Per Generation and Per Year in 4 Traits

Trait	Genetic Gain		
	Per Generation	Per Year	
NLB	0.055	0.016	lambs born
WWT	0.546	0.161	kilos live weight
SLW	1.310	0.385	kilos live weight
HFW	0.033	0.010	kilos greasy wool

Thus, the open nucleus breeding scheme operated by the Lands and Survey Department has an expected gain of 0.055 lambs born per generation. The lambing percentage as measured by lambs born to ewes lambing is expected to rise by 5.5 per cent units each generation. At the same time weaning weights are expected to rise as well as hogget fleece weight. But the size of the sheep, as measured by spring ewe weight is also expected to increase. Before these gains can be transformed into dollar terms, there are some husbandry factors which must be considered.

2.3 Husbandry Considerations

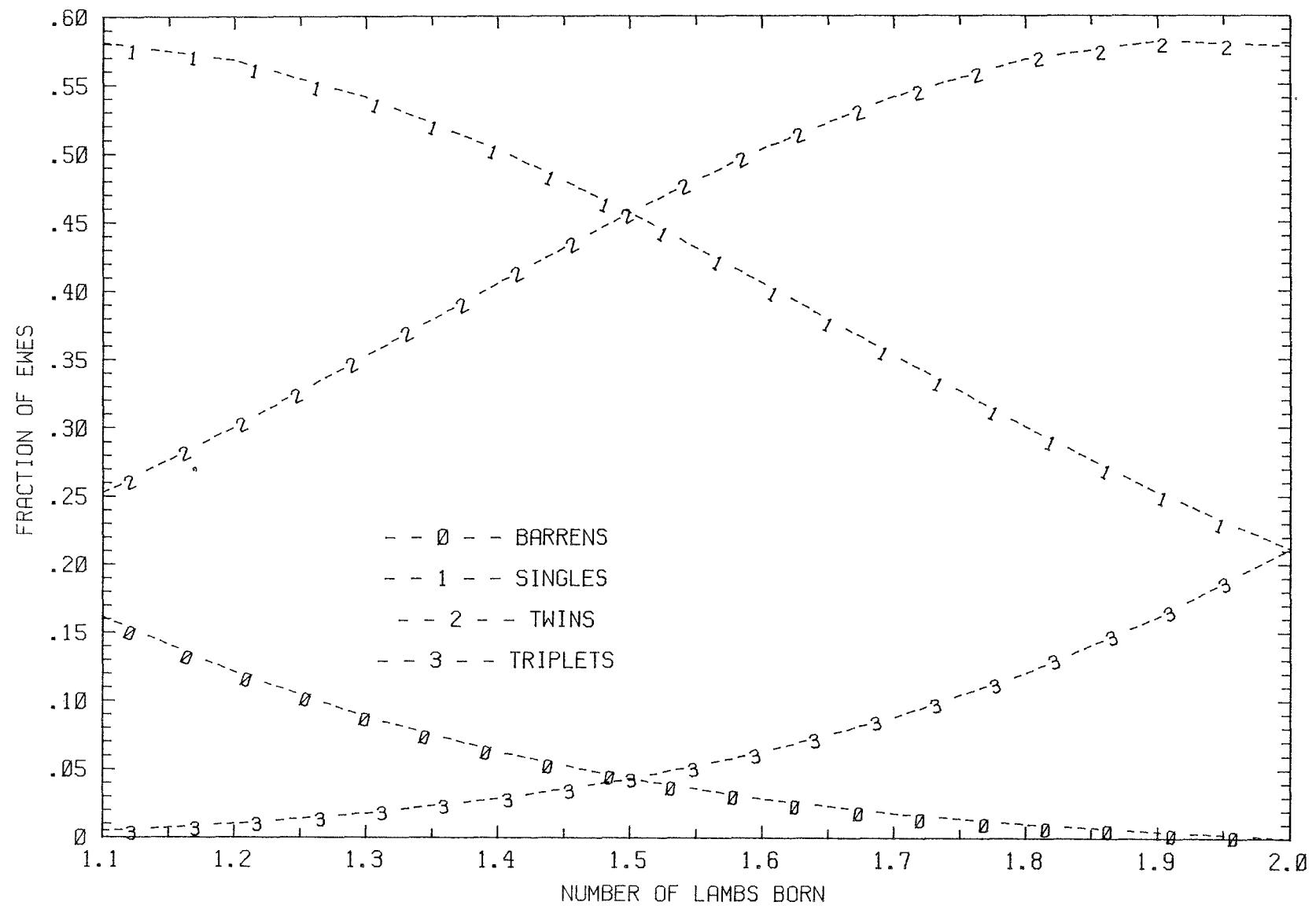
The recording and indexing scheme combined with an open nucleus breeding system is expected to result in more fertile ewes weaning heavier lambs, more wool, but they will be larger animals. Greater fertility implies more twins and triplets which have a higher death rate between birth and weaning. Moreover, the birth/rearing status also influences weaning weights. For instance a weaned lamb with the status of being born as a triplet and whose litter mates also survive will on average be lighter at weaning than a single lamb. Moreover, larger ewes will require more grass and, other things being equal, fewer can be carried on a grassland farm during the crucial winter period. In other words, the stocking rate will have to be adjusted downwards for larger and more fertile sheep.

Making adjustments to the gain in the four traits for these husbandry considerations is an essential step before assessing the social benefits from the Department's sheep breeding operations.

2.3.1 Fraction of barrens, singles, twins and triplets

To estimate the average weight of lambs weaned as a function of NLB and WWT, it is first necessary to estimate how the average number of lambs born per ewe mated will affect the fraction of barren ewes, ewes with singles, twins and triplets. Given the paucity of data available, a simple model was used to generate these fractions (Appendix 1 gives details of the model). Diagram 2 gives the results of the model which fit approximately data from the Lincoln College farms in the range of numbers of lambs born from 1.2 to 1.6.

DIAGRAM 2
DISTRIBUTION OF LITTER SIZE AS A FUNCTION OF NLB



2.3.2 Weaning Percentage and Weight of Lambs Weaned

The death rate between lambing and weaning varies with litter size. Figures of 0.13, 0.23, and 0.33 have been used as the death rates of singles, twins, and triplets respectively between lambing and weaning. Thus, a lamb born as a single has a 13 per cent chance of it dying before weaning and an 87 per cent chance of surviving. For twins and triplets it is assumed that deaths within a litter are independent events. In other words, in a litter of three, if the first lamb dies the chances of the second and third lambs dying still remain at 33 per cent. Using the binomial distribution the probability of x lambs surviving to weaning (given that n lambs are born and that the probability of a lamb dying in such a litter is q_n) is:

$$\text{Prob}(x) = \frac{n!}{x!(n-x)!} (1 - q_n)^x q_n^{n-x} \quad (6)$$

for $x = 0, 1, \dots, n$

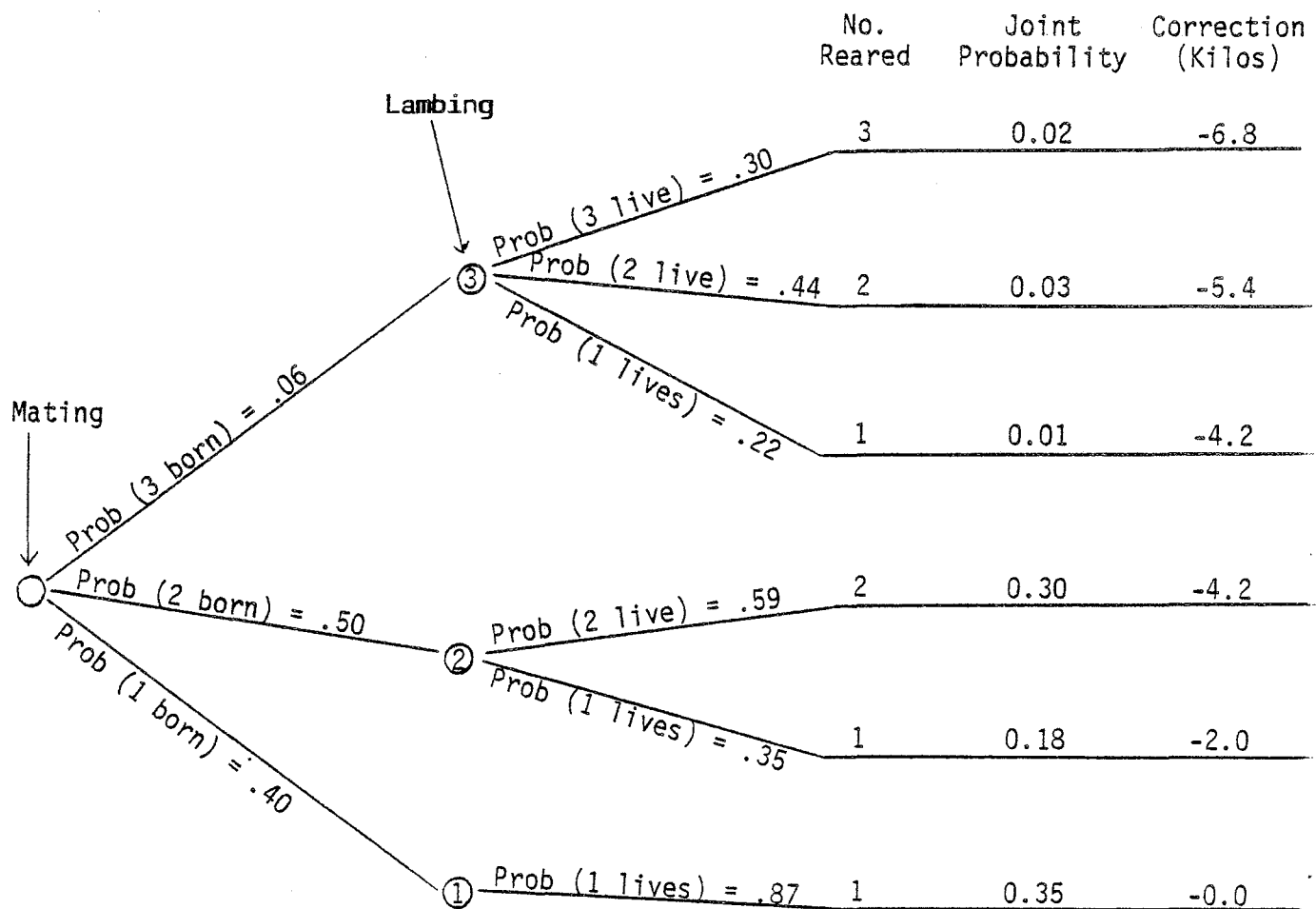
The resulting probabilities are displayed in Diagram 3 together with the probabilities derived from Diagram 2 for the case where the average number of lambs born per ewe is 1.6.

The last two lines of Diagram 3 show the calculation of the average number of lambs born (1.60) and weaned (1.26) per ewe mated.

Diagram 4 shows the relationship between percentage lambs weaned per ewe and percentage lambs born per ewe. This is slightly curvilinear as would be expected. As the lambing percentage as measured by numbers of lambs born rises, the proportion of multiple births rises which implies higher death rates.

The final column of Diagram 3 shows the correction factors used in Sheeplan to correct records to the standard case where a ewe lambs and rears a singleton. These corrections are very close to those specifically determined from Waihora data by McCall and Hight (1981). In Sheeplan corrections are added on to litters of more than one lamb. Here, to find the average weight of lambs weaned per ewe, the corrections are subtracted. In this study it is estimated that the average singleton weighed 17 kg at weaning initially.

Diagram 3

Probability Tree from Birth to Weaning

Prob. (1 lamb or more) 0.89

Prob. (0 lambs) 0.11

$$\text{Av. No. of Lambs Born} = 1(.40) + 2(.50) + 3(.06) = 1.60$$

$$\begin{aligned} \text{Av. No. of Lambs Weaned} &= 1(.35 + .18 + .01) + 2(.30 + .03) + 3(.02) \\ &= 1.26 \end{aligned}$$

Thus for the case of lambs born per ewe of 1.60, the average weight of lambs weaned per ewe is calculated in Table 6 from the information in Diagram 3.

TABLE 6
Calculation of the Average Weight of Lambs Weaned per Ewe

No. Born	No. Reared	Joint Prob.	Weaning Weight (kg)	Reared x Prob. x Weight (kg)
3	3	0.02	17 - 6.8	0.61
3	2	0.03	17 - 5.4	0.70
3	1	0.01	17 - 4.2	0.13
2	2	0.30	17 - 4.2	7.68
2	1	0.18	17 - 2.0	2.70
1	1	0.35	17 - 0.0	5.95
Average Weight of Lamb Weaned Per Ewe =				<u>17.77</u>

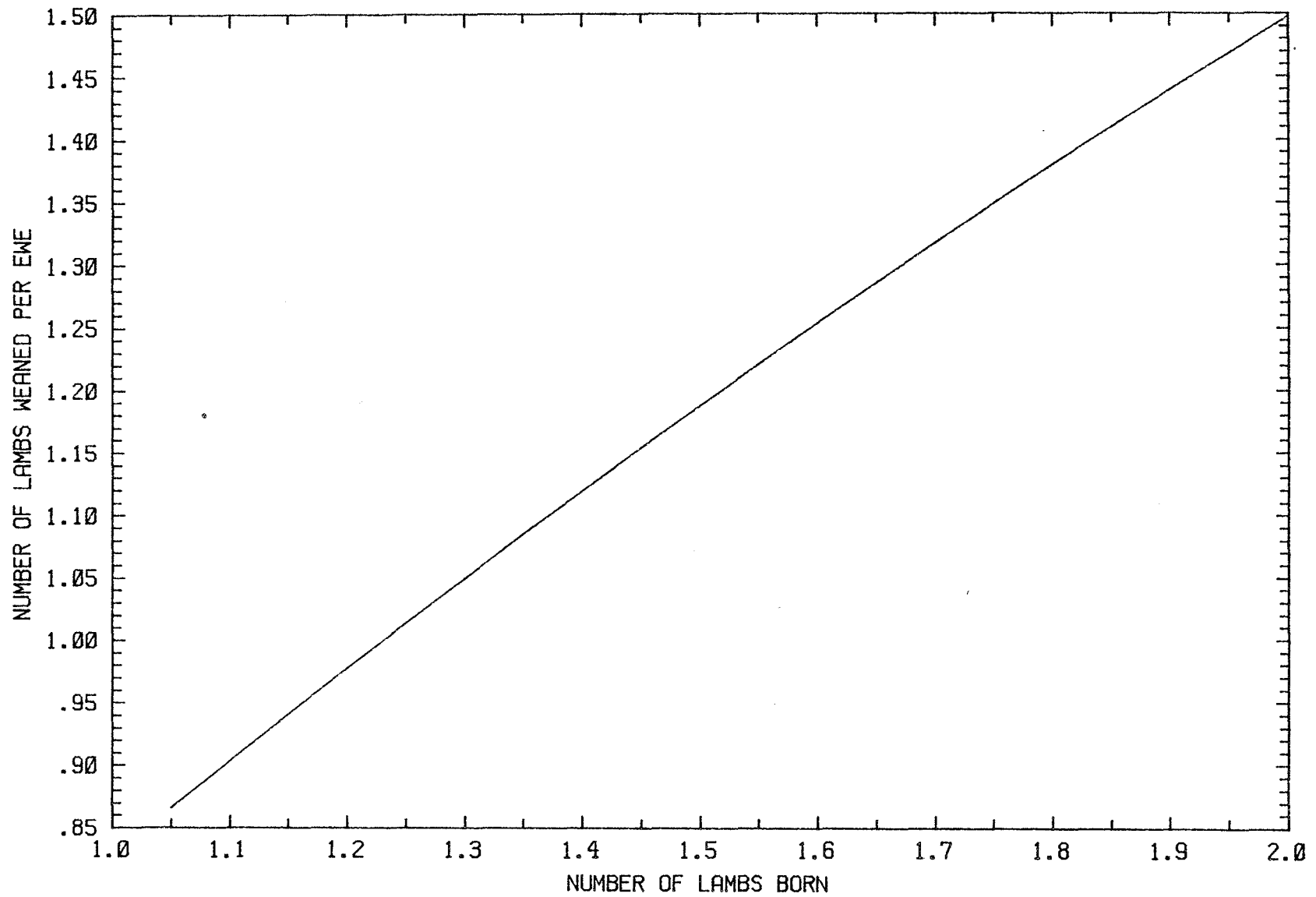
Diagram 5 shows the relationship between average weight of lambs weaned per ewe and percentage lambs born per ewe. The relationship is curvilinear reflecting both higher death rates in multiple births and their lower weaning weights.

2.3.3 Adjustment for Liveweight

The use of the Sheeplan index not only results in greater fertility but also in heavier ewes and heavier lambs at weaning. Table 3 shows that index selection which results in an extra 0.05 lambs born also results in 0.5 extra kilos per lamb at weaning and ewes which weigh 1.2 extra kilos as measured by spring liveweight.

Heavier ewes require more feed. At critical times such as the winter, the stocking rate on a sheep farm will have to be adjusted downwards for index selected ewes compared with unimproved sheep in order to maintain the level of nutrition. A downwards adjustment will not be necessary if the farm is understocked where increased stocking rates would not reduce performance per ewe. The pessimistic assumption is adopted here that downward adjustment of stocking rates would be required on all farms.

DIAGRAM 4
NUMBER OF LAMBS WEANED PER EWE AS A FUNCTION OF NLB



It is well known that maintenance requirements vary with the surface area of animals and that in turn surface area varies with the 0.75 power of the live weight (Brody, 1945). It follows therefore that maintenance requirements (F) are:

$$F = k W^{0.75} \quad (7)$$

where k is a constant for a species and W is the animal's liveweight

In order to adjust average weight of lamb weaned per ewe for the effects of greater ewe live weight, it is necessary to multiply it by the ratio of maintenance requirements of unimproved to improved ewes:

$$W_0^{0.75} / W_I^{0.75} \quad (8)$$

where W_0 and W_I are the liveweights of unimproved and improved ewes respectively.

2.3.4 Wool Weights

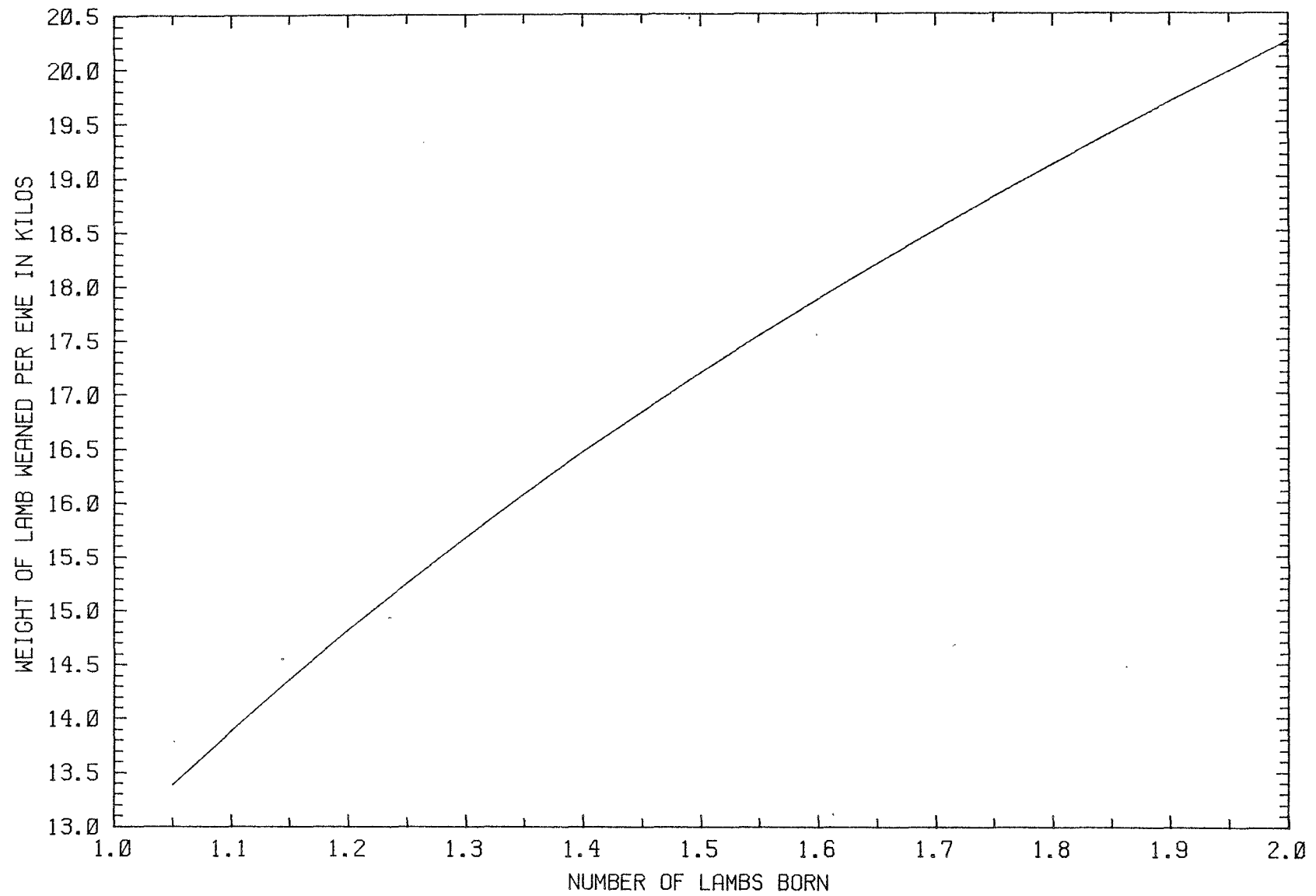
The application of the Sheeplan index results in an advance in hogget fleece weight (HFW). Strictly there is only one expression of this trait during the lifetime of a ewe, while average weight of lambs weaned per ewe (a function of NLB and WWT) has 5 or 6 expressions. However, the repeatability of fleece weight is fairly high (Turner and Young, 1969). Moreover ewes clip at least one additional fleece in their lifetime above the number of times they lamb. It is assumed that these two effects cancel each other out so that HFW measures average lifetime fleece weight per ewe. This would require a repeatability around 0.8 per fleece weight which is at the high end of the range reported in the literature.

However, a correction has to be made for the lower stocking rate implications of heavier ewes as is done for weight of lambs weaned.

2.4 Gain from Selection

Section 2.2 established the gain expected per year in NLB, WWT, SLW and HFW resulting from the open nucleus breeding system used by the Lands and Survey Department (Table 5). Section 2.3 gave the method of transforming these gains into average weight of lambs weaned and average

DIAGRAM 5
WEIGHT OF LAMB WEANED PER EWE AS A FUNCTION OF NLB



wool weight per ewe. It now remains to estimate the annual gains in terms of weight of lambs weaned and wool weight. Also required is the number of lambs weaned by ewe.

The equations below model the response to selection.

$$N_t = (P_{1t} + P_{2t} + P_{4t} + 2(P_{3t} + P_{5t}) + 3P_{6t})W_t^{.75} / W_0^{.75} \quad (9)$$

N_t is the number of lambs weaned per ewe after t years of selection.

P_{1t} , P_{2t} , P_{4t} are the probabilities of 1 lamb weaned in year t given 1, 2, and 3 lambs born respectively. P_{3t} and P_{5t} are the probabilities of 2 lambs weaned given twins and triplets born respectively. P_{6t} is the probability of triplets born and weaned.

$P_{jt} = f(1.2 + (t - 2)g_{NLB})$ for $j = 1, \dots, 6$ where g_{NLB} is the annual genetic gain for numbers of lambs born per ewe and 1.2 is the initial level.

W_t is the adult weight of ewes after t years of selection.

$W_t = 55 + (t - 2)g_{SLW}$ where g_{SLW} is the annual genetic gain for spring liveweight and 55 kilos is the initial level.

$$L_t = \sum_{j=1}^6 Q_j(17 + (t-2)g_{WWT} - C_j)P_{jt} W_t^{0.75} / W_0^{0.75} \quad (10)$$

where L_t is the weight of lambs weaned per ewe after t years of selection. Q_j is the number of lambs weaned; 1 for $j = 1, 2$, and 4, 2 for $j = 3$ and 5, and 3 for $j = 6$. g_{WWT} is the annual gain in weaning weight and 17 kilograms is the initial level.

C_j is the correction factor for weaned lambs.

$$H_t = (5 + (t-2)g_{HFW})W_t^{0.75} / W_0^{0.75} \quad (11)$$

where H_t is the weight of wool per ewe after t years of selection.

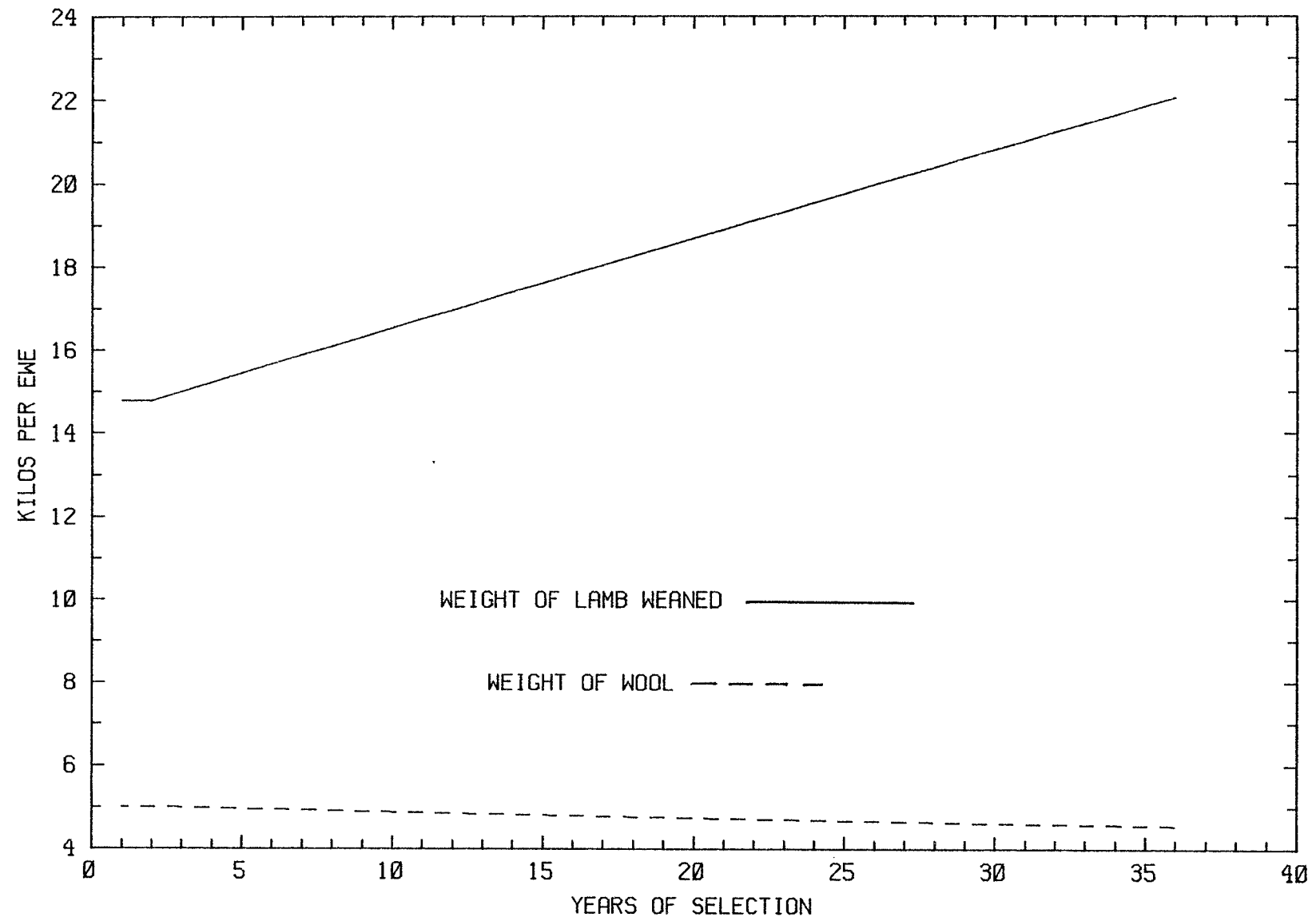
g_{HFW} is the annual gain in hogget fleece weight and 5 kilograms is the initial level.

As shown previously, the selection plan followed by the Department is expected to result in the annual genetic gain given in Table 3. Using a generation interval of 3.4 years and assuming a delay of 2

years between selection pressure and response, expected levels of average weight of lamb weaned and average wool weight over 36 years of selection were calculated, the results being shown in Diagram 6. While the weight of wool per ewe is expected to rise, the adjustment for stocking rate due to the increased weight of ewes results in a slight fall in wool per ewe after the liveweight correction has been made.

The next step in the analysis is to value these gains in economic terms and to match them against the costs of this selection program.

DIAGRAM 6
SELECTION RESPONSE



CHAPTER 3

ECONOMIC ANALYSIS

The purpose of this section of the analysis is to estimate the net social benefits of the open nucleus breeding scheme operated by the Lands and Survey Department. Social benefits are evaluated in cost-benefit analysis as the addition to consumption resulting from the adoption of a project. In this case the project is the continuation of the open nucleus breeding scheme. Additional consumption by New Zealanders from use of our resources represents an advance in economic efficiency.

Cost-benefit analysis (see Layard, 1972) is also concerned with the distribution of consumption - who gains and who loses as a result of the project's implementation. Taking for the moment that this project represents an advance consumption, it is clear that the losers are those pedigree breeders who would otherwise sell rams to the Lands and Survey Department. The gainers are the taxpayers of New Zealand upon whose behalf the land development is operated, and later those who are settled on the Rotorua District farms.

Returning to the question of economic efficiency, it is usual to use market prices or modified market prices (shadow prices) as the scale or numeraire by which advances in consumption are measured. In this case we require prices to value the extra weight of lambs weaned and "change in" weight of wool per ewe. We also must use prices to measure the extra inputs used to run the breeding scheme.

3.1 Prices of Meat and Wool

Real prices for lamb and wool measured in 1981 dollars at the farm gate have been determined by Laing (1981, pers. comm.).

These prices are those received by farmers per kilo of lamb and include bare meat, pelt and wool payments. They are adjusted for price stabilisation, and SMP and other payments. These prices are based on the North Island PM lamb using the average of the mid month schedule between December and May. Over the 1968-1981 period this series averaged \$1.7 per kilo.

This price was used as the basis for estimating future lamb prices. Two modifications were considered for estimating a shadow price.

(a) Use of the marginal revenue was considered rather than the price of lamb on the grounds that, given a downward sloping demand curve, extra lamb supplies resulting from projects such as this would reduce the price of lamb. However, while the demand curve is undoubtedly downward sloping on individual markets (Philpott, 1961), the opening up of new markets results in a right hand shift of the overall demand curve for New Zealand lamb. In fact new markets have opened up and it is assumed that this process will continue into the future - compensating at least for the increased supplies from New Zealand to world markets. Hence, the cautious approach of using marginal revenue as a shadow price was rejected.

(b) It is widely recognised that the New Zealand dollar is under-valued. An extra dollar earned in overseas exchange results in more than 1 dollar's worth of additional consumption in New Zealand. This is recognised by Treasury in project evaluation studies who shadow price overseas exchange earning by 10 per cent (Stonyer, 1977). The F.O.B. value of lamb is approximately twice the farm gate price. Adopting \$1.7 per kilo as the projected future farm gate price of lamb, a further \$1.7 is required to "process" it bringing the F.O.B. price to \$3.4. Increasing this by 10 per cent brings it to a shadow price F.O.B. of \$3.74 and subtracting the processing cost of \$1.7 gives a shadow price for lamb at the farm gate of \$2.04 per kilo of carcass.

A further conversion is required to convert carcass prices into the value of the liveweight of weaned lamb. The killing out fraction is about 0.47, hence the shadow price for liveweight weaned is $\$2.04 \times .47 = \0.96 .

Wool prices have averaged \$3.0 per kilo at the farm gate since 1968 (in 1981 dollars). New Zealand has a relatively small share of the world market. Moreover the elasticity of demand for wool is high because it substitutes for synthetics and other fibres. As with lamb prices, the use of marginal revenue as a shadow price was rejected.

The "processing costs" are relatively small. So to shadow price farm gate prices, 10 per cent was added bringing it up to \$3.3 per kilo.

3.2 Costs of Extra Lambs

Selection implies raising the number of lambs born per ewe and the number weaned. This implies some extra costs. Feed costs have been ignored because when lambs are at foot most farmers have grass going to waste. However, operations such as tailing and drenching with anthelmintics and trace elements have a per lamb cost. The per ewe costs for these operations rise as the litter size increases. For three drenchings at \$0.15 each, the per ewe cost for a ewe weaning an extra lamb is \$0.45. These costs of a large litter size have been incorporated into the economic evaluation.

3.3 Costs of Recording and Selection

Table 7 shows a comparison of the budgeted cost for 1981/82 of the nucleus flock and the base flocks run by the Rotorua Land Development District (Craig, 1981; pers. comm.).

TABLE 7
Budgeted Costs 1981/82

	\$ Per Stock Unit	\$ Per Ewe ^a
Nucleus Flocks	21.33	30.33
Base Flocks	18.72	26.74
Difference	2.51	3.59

a Estimated

The additional costs of running the nucleus flocks estimated on a per ewe basis include the additional staff required for handling the breeding operations at the farm level. They do not include interest and depreciation charges on extra houses, yards, and weighing facilities. Since these are a sunk cost, it is inappropriate to include them. To the estimated extra cost per ewe of \$3.59 for 9,000 ewes in the nucleus must be added the cost of employing and servicing a liaison officer, estimated at \$30,000 annually, bringing the total cost of the nucleus

breeding scheme for recording and selection to \$62,310 or \$0.30 per ewe over the entire scheme of 209,000 ewes.

However, there are some cost savings in that rams are not purchased from the pedigree breeding industry. At one ram purchased annually per 100 ewes at \$100 a piece, there are cost savings of \$1.00 per ewe, totalling \$209,000 annually. There are no net recording and selection costs of the Rotorua Land Development Districts breeding scheme; rather they represent a benefit of \$0.70 per ewe (\$1.00 - 0.3).

3.4 Annual Net Benefit

Given prices for lamb and wool the marginal annual net benefit after t years of selection (b_t) can be estimated thus:

$$b_t = P_W (H_t - H_0) + P_L (L_t - L_0) - P_D (N_t - N_0) - K \quad (12)$$

where P_W and P_L are the shadow prices of wool and lambs per kilo respectively. P_D is the cost of extra lambs and K is the annual cost of recording and selection.

3.5 Allowing for Time

The net social benefits of selection for unimproved sheep do not occur immediately. They take time to achieve. Net social benefits are delayed. In order to make comparisons with other projects which have different time patterns, a method is required which brings all projects to a common base. The usual base is the present value in dollars.

$$P(i) = \sum_{t=1}^n b_t (1+i)^{-t} \quad (13)$$

where b_t is the net benefit accruing after 1,2, ... n years and i is the social rate of interest. P is the present value.

In this analysis, it is assumed that the project benefits would continue ad infinitum by letting $n = \infty$. As pointed out earlier, selection was planned to continue for ten generations with improvement continuing for 36 years after a two year initial delay. After 36 years no further improvement occurs, but the gain achieved at that point persists.

The present value is:

$$P(i) = \sum_{t=1}^{36} b_t(1+i)^{-t} + \frac{b_{36}}{i} (1+i)^{-36} \quad (14)$$

The penultimate term capitalises the steady state flow of benefits to infinity at year 36 and $(1+i)^{-36}$ discounts these back to a present value.

While the present value is a useful criteria for comparing the contribution of the project to economic efficiency, it is often simpler to express the present value in terms of the equivalent annual return. This is the equivalent annual net benefits over the same life of the project which have a present value of $P(i)$.

$$P(i) = \text{EAR} \sum_{t=1}^{\infty} (1+i)^{-t} \quad (15)$$

$$\text{and } \text{EAR} = i P(i) \quad (16)$$

Deciding on the social rate of interest is a difficult task (Bird and Mitchell, 1980). Essentially this is the rate of interest which models the value New Zealanders place on consumption now as compared with consumption in the future. Working in 1981 dollars, New Zealanders should be indifferent between \$1 now and $\$1(1+i)^n$ in n years time.

Treasury have set $i = 0.1$ as the social rate of discount of public projects (Stonyer, 1977). In the author's opinion this is on the high side and a value of 0.05 is favoured; however, a range of social rates of interest that includes both these values has been used to evaluate this project.

3.6 Uncertainty Measures

Almost all the variables used in this model for estimating the equivalent annual return are subject to uncertainty. In the case of the technical variables such as the genetic gains for NLB, WWT, SLW, and HFW, the authors of Sheeplan and its variant used by the Department have used statistical estimates from many sources which may or may not hold good in the case of Romney sheep improvement at Rotorua. The same uncertainty exists concerning the economic variables. We are not sure that prices which have prevailed in the past will hold in the future.

Hence an element of subjectivity exists for both the technical and economic variables used to estimate the future equivalent annual return from the Department's breeding operations.

To overcome the problem, at least partially, historical levels of each variable are assumed to be their expected values. For each uncertain variable a subjective standard deviation has been estimated, making explicit the author's judgement about its uncertainty level. The first partial derivative of the equivalent annual return with respect to each uncertain variable was also calculated by numerical methods.

Using these partial derivatives d_k (for the k^{th} uncertain variable), three measures of uncertainty were calculated.

1. 10 per cent Sensitivity: This is the change in EAR for a 10 per cent change in the k^{th} uncertain variable where all other variables are held at their expected values.

$$10 \text{ Per cent Sensitivity} = 0.1A_k d_k \quad (17)$$

where A_k is the expected value of the k^{th} uncertain variable.

2. Sensitivity to a standard deviation change: This is the change in EAR for a 1 subjective standard deviation change in the k^{th} uncertain variable where all other variables are held at their expected values.

$$\text{S.D. Sensitivity} = \hat{\sigma}_k d_k \quad (18)$$

where $\hat{\sigma}_k$ is a subjective estimate of the standard deviation of k^{th} uncertain variables.

3. Standard deviation of the EAR: This is the subjective standard deviation of the expected EAR. (Springer et. al., 1968).

$$\hat{\sigma}_{\text{EAR}} \approx \sum_i \sum_j d_i d_j \hat{r}_{ij} \hat{\sigma}_i \hat{\sigma}_j \quad (19)$$

where \hat{r}_{ij} is the subjective correlation coefficient between the i^{th} and the j^{th} uncertain variables. As these are particularly difficult to judge, they were all assumed to be zero except for one variable combination. Because long run lamb and wool

prices are jointly affected by world economic conditions a subjective correlation coefficient of 0.7 was used between these two uncertain variables.

The standard deviation of the EAR provides an uncertainty measure of the expected EAR. Assuming that historical levels are unbiased estimates of the expected values of the variables used, and that the resulting distribution of the EAR is Normal, then probability statements can be made concerning the chances of the EAR being below certain levels.

The two measures of sensitivity (10 per cent sensitivity and S.D. sensitivity) indicate which variables need estimating with more precision or which must be monitored during the execution of the project to see if the project should be closed down or modified. The third measure - the standard deviation of the EAR can be used to judge whether the project should be adopted taking into consideration both expected gains and uncertainty when compared with other projects.

CHAPTER 4

ECONOMIC EVALUATION OF THE BREEDING SCHEME

Having described the methods used to evaluate the breeding operations used by the Lands and Survey Department, it is now appropriate to define the exact project being evaluated and to present the results.

The project being evaluated is the continuation of the open nucleus breeding scheme based on Waihora. At first the flocks in the base will be owned by the Lands and Survey Department; later by settlers taking over their farms. In evaluating this project, gains in the four Sheeplan traits will occur over ten generations. The alternative with which the project is evaluated against is to go back to buying rams from the pedigree breeding industry at \$100 each. The purchased rams will maintain the ewes for the four traits at the genetic level which has already been achieved by the Lands and Survey breeding operations.

Table 8 summarises the expected values used in the model.

Diagram 7 gives the extra cash flow per ewe resulting from selection. It commences at a gain of 70 cents because the breeding scheme is cheaper than buying rams, and rises almost linearly to just over \$7 per ewe in year 36.

Finally, Diagram 8 shows the equivalent annual return per ewe using interest rates in the range from 1 per cent to 20 per cent. At 5 per cent the equivalent annual return per ewe is \$3.75 and at 10 per cent it falls to \$2.42. Translating these figures into the value for the 209,000 ewes in the Rotorua Development District the return amounts to the equivalent of almost \$800,000 and \$500,000 annually for a social rate of interest of 5 per cent and 10 per cent respectively. These represent significant amounts of consumption.

The estimate of the equivalent annual return per ewe of \$3.75 for the breeding operation is subject to some uncertainty. Table 9 shows the expected values of the 'uncertain' variables used in the model for calculating EAR together with a set of corresponding subjective standard

TABLE 8

Summary of Expected Values

1. Selection Intensities for

best nucleus both rams used in nucleus	0.073
next best nucleus born rams used in base	0.636
best nucleus born ewes used in nucleus	0.727
best base born ewes used in nucleus	0.170
2. Proportion of nucleus ewes 'promoted' from base 0.207
3. Genetic gain for improvement of 1 standard deviation on index

NLB	0.05	per ewe
WWT	0.50	kilos
SLW	1.20	kilos
HFW	0.03	kilos
4. Generation Interval 3.4 years.
5. Variance of NLB 0.65^2 .
6. Probability of survival from birth to weaning

Single	0.13
Twin	0.23
Triplet	0.33
7. Depression of weaning weight compared with a singleton

a single born as a twin	2.0 kilos
a twin born as a twin	4.2 kilos
a single born as a triplet	4.2 kilos
a twin born as a triplet	5.4 kilos
a triplet born as a triplet	6.8 kilos
8. Initial level of

NLB	1.2	lambs	
WWT	17	kilos	(for a singleton)
SLW	55	kilos	
HFW	5	kilos	
9. No response to selection in first two years, a response for next 34 years, and no response thereafter.
10. Expected shadow price for

Weaning liveweight	\$0.96 per kilo
Wool	\$3.3 per kilo
11. Cost per lamb for drenching, etc. \$0.45
 Cost per ewe for recording, etc. \$0.70
12. Social discount rate $i = 0.01$ to 0.20

DIAGRAM 7
EXTRA CASH FLOW AS A FUNCTION OF YEARS OF SELECTION

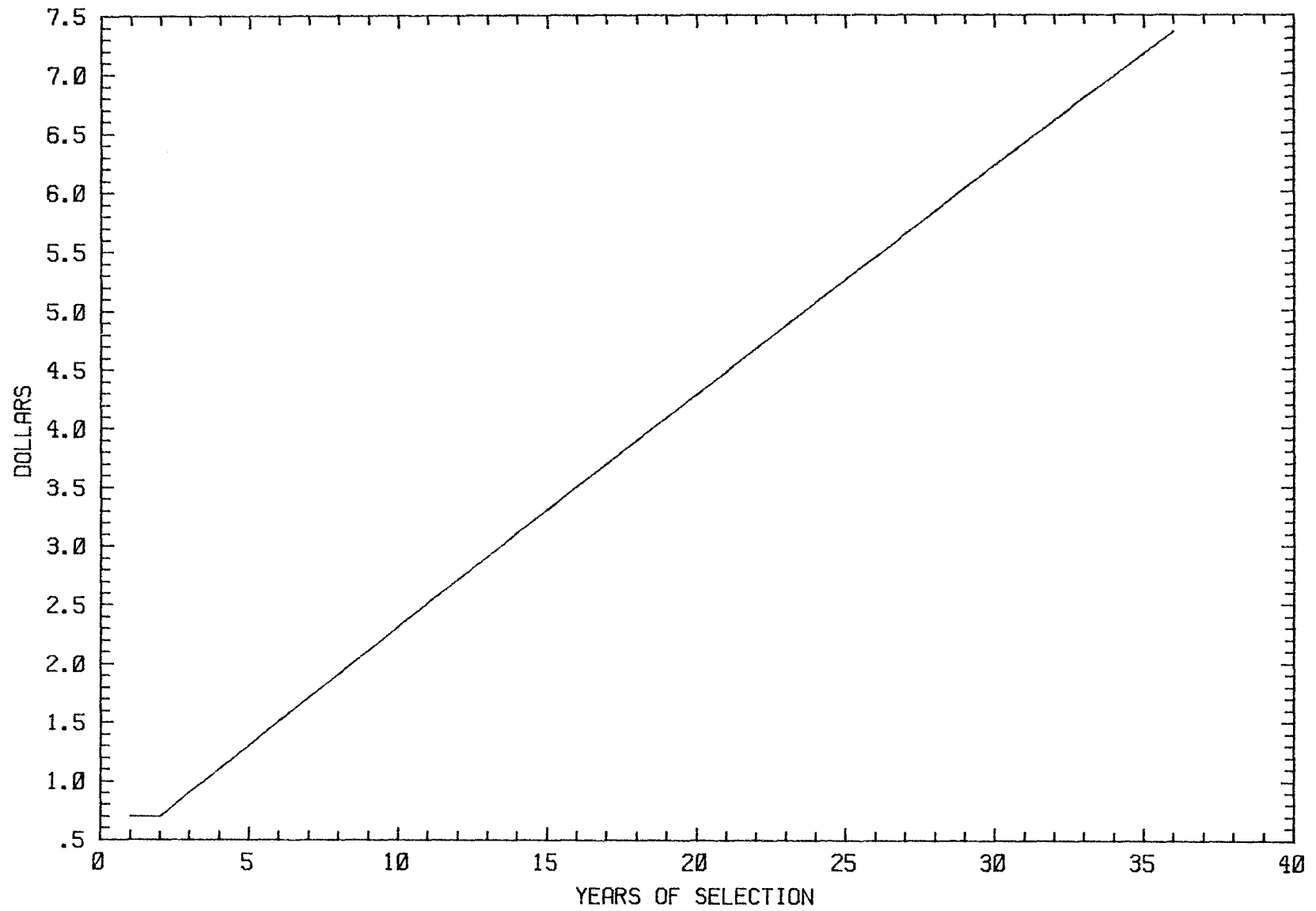
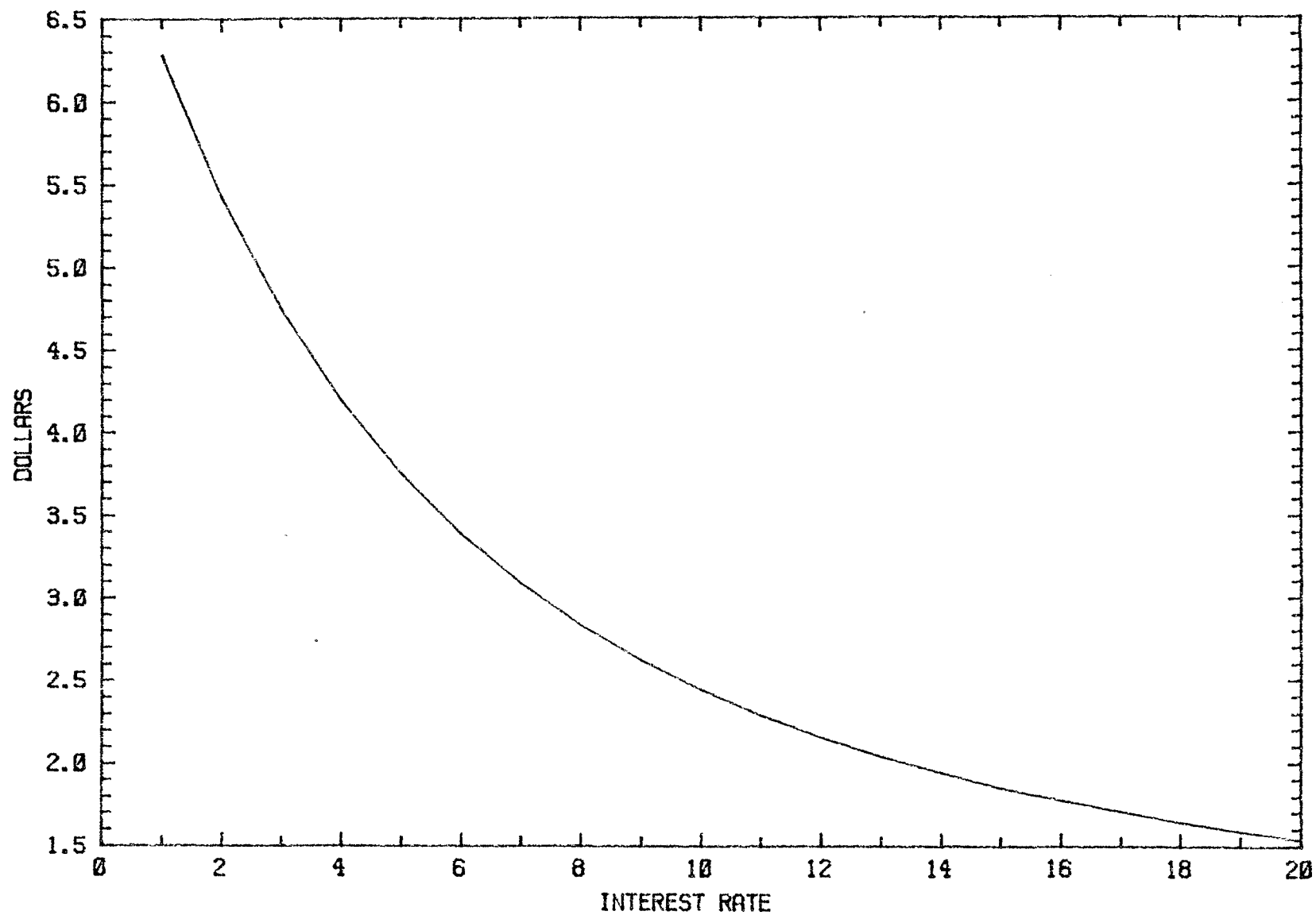


DIAGRAM 8
EQUIVALENT ANNUAL RETURN AS A FUNCTION OF INTEREST RATE



deviations. Thus, the expected long run average price of a kilo of liveweight of weaned lamb was \$0.96. The subjective standard deviation was \$0.20 and a normal distribution was assumed. The author's opinion is that there is a 70 per cent chance that future long run average lamb prices will fall in the range of plus or minus 1 standard deviation of the expected level, that is within the range of \$0.8 and \$1.2.

The column headed '10 per cent Sensitivity' shows the change in EAR for a 10 per cent change in the uncertain variable. The column headed 'S.D. Sensitivity' shows the change in EAR for a one subjective standard deviation change in the uncertain variable.

TABLE 9

Sensitivity Analysis

Uncertain Variable	Expected Value	Subjective S.D.	10 Per Cent Sensitivity	S.D. Sensitivity
Lamb price	0.96	0.2	0.38	0.80
Wool price	3.30	0.7	-0.07	-0.15
Cost per extra lamb \$	0.45	0.09	-0.004	-0.007
Cost per ewe \$	-0.70	0.20	-0.07	-0.20
Interest rate	0.05	0.02	-0.20	-0.80
Generation number	10.00	3.00	0.17	0.52
Genetic Gain NLB	0.05	0.015	0.26	0.78
Genetic Gain WWT	0.50	0.15	0.26	0.76
Genetic Gain SLW	1.20	0.36	-0.29	0.87
Genetic Gain HFW	0.03	0.01	0.04	0.13
Extra Lamb Prob. ^a	0.10	0.02	-0.09	-0.22

^a The extra probability of a lamb dying from birth to weaning given that it has an extra sibling in its litter.

Examination of Table 9 shows that the EAR is not particularly sensitive to the cost per lamb, cost per ewe, genetic gains in hogget fleece weight, the price of wool, and the extra probability of a lamb dying from birth to weaning given that it has an extra sibling in its litter.

On the other hand, the EAR is sensitive to the price of lamb, the social rate of interest, and the genetic gains in NLB, WWT, and SLW. These are the variables which should be monitored in future decisions about the project being continued.

In the very unlikely event that all the uncertain variables have been estimated over optimistically by one subjective standard deviation, then the EAR has been over-estimated by \$5.24. This is the sum of the absolute values shown in the last column of Table 9. Then the EAR would be $\$3.75 - 5.24$ or a loss of \$1.49 per ewe.

The standard deviation of the EAR calculated using equation 16 is \$1.89. The breakeven point for the project is where the EAR equals zero dollars. The expected EAR of \$3.75 lies 2 standard deviations above the breakeven point ($3.75/1.89 = 2$). Assuming that EAR is normally distributed, there is only a $2\frac{1}{2}$ per cent chance that the project will not breakeven compared with buying rams from the pedigree breeding industry.

In conclusion, therefore, the net social benefits per ewe have been estimated at \$3.75 with a very small chance that the project will not at least breakeven.

CHAPTER 5

DISCUSSION AND RECOMMENDATIONS

5.1 Efficiency and Distribution

The objective of economic and social policy is to raise the level of welfare of the New Zealanders where welfare is used in the economic sense. There are two sub-objectives which raise welfare, increasing consumption of goods and services from the resources available (increasing economic efficiency) and improving the distribution of goods and services. Government 'improves' the distribution of goods and services through pensions for the over 60's, health and education services and so on. It can also alter the distribution of goods and services through government projects. The siting of a project, for instance, will provide gains for local people often at a cost to others.

The breeding operations of the Lands and Survey Department can be expected to increase economic efficiency and may well improve distribution.

The economic analysis indicates an expected equivalent annual return of \$3.75 per ewe or \$800,000 annually in 1981 dollars, representing a gain of this amount in increased consumption of goods and service. However, this only takes into consideration the benefits to the Rotorua District for the Lands Department representing the taxpayer and the subsequent settlers. There are possible external benefits which have not been evaluated. The Department has started selling rams to other users of Sheeplan recording and this has the potential for making further increases in economic efficiency beyond the boundaries of the Rotorua Land District.

One way of valuing these external benefits is to value the 40 rams sold each year from the Waihora nucleus at their sale price of \$800 resulting in an additional \$0.15 cents per ewe to the EAR. However, the sale price may considerably undervalue the social benefits to New Zealand.

An alternative procedure would be to assume that the 40 rams sold to outsiders produce the same benefits per head as the 80 rams selected each year for the Waihora nucleus flock. The external benefits

would then amount to \$400,000 annually bringing the total benefits up from \$800,000 to \$1.2m annually or from \$3.75 per ewe to \$5.66 per ewe. If the Waihora nucleus became recognised by the farming community as being ahead of all other sources of genetic material, then the extra external benefits of the rams sold could be many times greater than this estimate because such recognition could place the Waihora nucleus at the top of the breeding hierarchy.

A further possible external benefit concerns the influence which the Waihora nucleus could have on the market for rams. The stud stock market has many economic imperfections (McArthur, 1980). A serious imperfection is the difficulty which the buyer experiences in assessing the expected economic value of a stud animal because of environmental effects. This gives the seller an opportunity to exaggerate the animal's economic value without danger of post-sale repercussions. Moreover, imperfect information gives the seller an opportunity to mould the values that buyers place on various traits to fit the attributes of the animals he sells. This is done by promotion. It should be pointed out that these imperfections are very common in other markets too.

Currently there is a strong apparent interest in Sheeplan and selection using objective methods particularly in the co-operative breeding schemes which are operating on the same lines as the Waihora nucleus. However, these groups too may see short term economic advantage in exploiting the market imperfections for their rams and revert in part to traditional breeding methods. The influence of the Waihora nucleus in the market may discourage this possible reversion.

So much for both the internal and external net benefits of the Department of Lands and Survey's breeding operations.

As pointed out earlier, there is a distributional implication of the breeding operation in that now the Lands and Survey Department breeds its own rams conferring benefits to taxpayers and settlers, and it no longer buys rams from the pedigree breeding industry and saves \$200,000 annually. This means that the level of consumption of pedigree breeders may be less than previously. It seems likely that the level of consumption of pedigree breeders is on average higher than taxpayers and settlers. On the argument of diminishing marginal

utility, it would seem that the redistribution brought about by the Lands and Survey breeding operations is improving economic welfare.

However, more than consumption of goods and services purchased with money are at stake here. Improvement of animals through breeding is a means of rural recreation and social prestige. The value of these intangibles are hard to assess. The gainers of recreation and prestige have been government servants who have planned and executed the breeding operations at Waihora. The losers have been the traditional pedigree breeders. It is a matter of personal judgement as to whether this redistribution has improved welfare overall.

5.2 Recommendation

Taking into consideration both efficiency and distributional questions, it is recommended:

1. That the Waihora nucleus be maintained for supplying rams to flocks within the Rotorua Land Development District and other Lands and Survey Districts.
2. That the Waihora nucleus continue after the Rotorua farms are settled to supply settlers and others with rams.
3. That the Waihora nucleus breeding operation be extended to other Lands and Survey Development Districts.
4. That the Waihora nucleus continue selling rams to private breeders - particularly those in co-operative breeding schemes using Sheeplan.
5. That objective experiments be conducted to assess the genetic deviation between rams sold by the pedigree industry to commercial farmers, and rams from Waihora.

REFERENCES

- BIRD, P.J.W.N. and MITCHELL, G. (1980) 'The Choice of Discount Rate on Animal Breeding Investment Appraisal', *Animal Breeding Abstract* 48(8), pp.499-505.
- BRODY, S., (1945) 'Bioenergetics and Growth', Reinhold, N.Y.
- CLARKE, J.N. and RAE, A.L., (1976) 'Sheeplan Advisers Manual', Ministry of Agriculture and Fisheries.
- CUNNINGHAM, E.P. (1969) 'Animal Breeding Theory', Oslo University.
- FALCONER, D.S. (1964) 'Introduction to Quantitative Genetics', Oliver and Boyd, Edinburgh.
- HIGHT, G.K., GIBSON, A.E., WILSON, D.A., and GUY, P.L. (1975) 'The Waihora Sheep Improvement Programme', *Massey Sheepfarming Annual* 1975, p.67-89.
- JAMES, J.W. (1977) 'Open Nucleus Breeding Systems', *Anim. Prod.*, 24:287-305.
- LAYARD, R. (1972) 'Cost Benefit Analysis' Harmondsworth, London.
- McARTHUR, A.T.G. (1980) 'Economic Considerations in Adopting Technical Advances in Breeding', *Proc. World Conference on Sheep and Beef Cattle Breeding*, Massey University, New Zealand.
- McCALL, D.G. and HIGHT, G.K. (1981) 'Environmental influences on hogget lambing performance and the relationship between hogget and two-tooth lambing performance', *N.Z. J.Ag.Res.* 24, 145-152.
- PHILPOTT, B.P. (1961) 'Economic Research on Fat Lamb Prices', *Proc. Lincoln College Farmers Conference* 1961, 16-25.
- RAE, A.L. (1970) 'The Future of Agricultural Research in New Zealand: Animal Genetics and Breeding Possibilities', *New Zealand Agricultural Science* 4(4), 10-13.
- STONYER, E.J., et al. (1977) 'Cost Benefit Procedures in New Zealand Agriculture', *Economics Division, Ministry of Agriculture and Fisheries*, New Zealand.
- SPRINGER, C.H., HERLIHY, R.E., MALL, R.T. and BEGGS, R.I. (1968) *Probabilistic Models*, Irwin, Illinois.
- TURNER, H.N. and YOUNG, S.S. (1969) 'Quantitative Genetics in Sheep Breeding', MacMillan, Australia.

APPENDIX 1

Distribution of Litter Size Model

This model gives the distribution of litter size as a function of the number of lambs born per ewe (NLB).

Let P_0 be the fraction of ewes with zero lambs (barren).

P_1 be the fraction of ewes lambing 1 lamb.

P_2 be the fraction of ewes lambing 2 lambs.

P_3 be the fraction of ewes lambing 3 lambs.

The expected number of lambs born equals NLB symbolised by μ .

$$0P_0 + 1P_1 + 2P_2 + 3P_3 = \mu \quad (1)$$

The variance or the expected deviations from the mean squared is symbolised by σ^2 . Clarke and Rae (1975) quote 0.65^2 as an estimate of the variance of NLB.

$$(0 - \mu)^2P_0 + (1 - \mu)^2P_1 + (2 - \mu)^2P_2 + (3 - \mu)^2P_3 = \sigma^2 \quad (2)$$

Clarke and Rae assume that NLB is normally distributed. This implies that the expected deviations from the mean cubed are zero.

$$(0 - \mu)^3P_0 + (1 - \mu)^3P_1 + (2 - \mu)^3P_2 + (3 - \mu)^3P_3 = 0 \quad (3)$$

The fraction of barrens, singles, twins, and triplets must all be positive and sum to unity.

$$P_0 + P_1 + P_2 + P_3 = 1 \quad (4)$$

Equations 1 to 4 reduce to

$$\begin{aligned} 0P_0 + 1P_1 + 2P_2 + 3P_3 &= \mu \\ 0P_0 + 1P_1 + 4P_2 + 9P_3 &= \mu + \sigma^2 \\ 0P_0 + 1P_1 + 8P_2 + 27P_3 &= 3\mu\sigma^2 + \mu^3 \\ 1P_0 + 1P_1 + 1P_2 + 1P_3 &= 1 \end{aligned} \quad (5)$$

Given the variance is constant at 0.65^2 ($\sigma^2 = 0.65^2$), equation (5) can be solved for any value of μ (number of lambs born) to give the associated fraction of barrens (P_0), ewes lambing singles (P_1), ewes lambing twins (P_2) and ewes lambing triplets (P_3). These fractions are always positive (fortunately) in the range of NLB from 1.1 to 2.0.

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